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Gamma radiation influence on germination characteristics of barley

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Abstract

Nuclear irradiation is considered among the practical techniques for improving germination, increasing yield, and enhancing the quality of agricultural products. To investigate the influence of gamma irradiation on germination characteristics of barley, a two-factor factorial experiment was conducted in a completely randomized design. Experimental factors included five barley cultivars (Youssef, Bahman, Makouee, and Behrokh) and radiation (Radiation treatment: gamma radiation with a dose of 200 Gy, Control: no radiation). Indices that were studied included germination rate, coleoptile emergence rate, mean germination time, mean coleoptile emergence time, final germination percentage, final coleoptile emergence percentage, coleoptile length, radicle length, the ratio of coleoptile length to radicle length, radicle dry matter, and coleoptile dry matter. Although germination rate, coleoptile emergence rate, coleoptile length, radicle length, and radicle dry weight of irradiated cultivars decreased compared to the control, the irradiation treatment significantly increased the percentage of final germination (93.58%), coleoptile length to radicle length (2.44), and coleoptile dry weight (0.22 g) compared to control.

1. Introduction

Barley (*Hordeum vulgare* L.) is a strategic crop that plays an essential role in food security in Iran and worldwide. Therefore, barley occupies the second place in the country after wheat with a cultivated area of 1.65 million hectares and is considered the fourth crop in the world after wheat, corn, and rice [1]. Accordingly, investigating all methods and techniques that might increase the yield of this important crop is an important topic of agricultural research.

Germination is the first stage of crops growth and development [2]. Seed agronomic quality is one of the most critical inputs in barley crop production and is of particular importance in achieving an optimal yield [3]. Despite the advanced crop management technologies, seed germination and the proper establishment of seedlings are still crucial phases in production cycles. Thus, a strong correlation exists between successful crop production and the successful seed germination and strong seedlings establishment. Therefore, new techniques are constantly being implemented to investigate their effects on germination, yield, and agricultural products quality. Gamma rays irradiation is one of these techniques [4].

Gamma rays are ionizing radiations and are the most energetic form of electromagnetic radiations with an energy level of about 10 to several hundred kilowatts. Therefore, their penetration power is higher than other types of radiation, such as alpha and beta [5][6]. Gamma irradiation has many applications that can be implemented in agriculture to improve growth, increase resistance to biotic and abiotic stresses, and increase grain yield and quality [7].

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Various researches concentrated on the positive effects of gamma irradiation on germination and post-germination attributes for many plants such as wheat [7-9], corn [10], lentils [11], vegetable crops [12], and barley [13][14]. Therefore, considering the strategic importance of barley crop, this experiment was conducted to investigate the effect of cultivar and gamma radiation treatment on germination and seedling growth indices of some barley cultivars.

2. Material and Methods

2.1. Experiment material

The experiment was carried out in the laboratory of the weed research department of the Plant Protection Research Institute of Iran in 2015. Experimental factors included cultivars (Youssef, Bahman, Makouee, and Behrokh) and radiation (Radiation treatment: gamma radiation with a dose of 200 Gy, Control: no radiation). The cultivars were introduced between 1991 and 2014 and had a significant area under cultivation in Iran (Table 1).

Table 1. Growth and yield attributes of the barley cultivars used in the present experiment.

Cultivars	Year of introduction	Yield (t ha^{-1})	Height (cm)	Rows[a]	Growth Type	Maturity Type
Makouee	1991	5.5-6.5	105	6	Winter	Late
Bahman	2009	5.5-6.5	80	6	Winter	Late
Youssef	2010	5.5-6.5	90	6	Spring-Winter	Early
Behrokh	2014	6-6.5	76	2	Spring-Winter	Semi-early

a The number of seed rows per ear
The information was provided by the promotional brochures of the Agricultural Research, Education and Extension Organization (Karaj Seed and Plant Breeding Institute).

Each of the experimental treatments (irradiated and control) for each cultivar consisted of four petri dishes (four replications) with 40 seeds placed on filter paper at appropriate intervals. Petri dishes were transferred into a seed germinator at a temperature of 15 °C.

2.2. Germination attributes

At the beginning of germination, germinated seeds were counted daily at a certain hour of the day for 8 days, starting from the 2nd day after transferring to the germinator. The germination was considered successful when the radicle reached 2 mm in length. Monitoring continued until all the seeds had germinated or until it was certain that they could not germinate. Germination indices including germination rate (GR), coleoptile emergence rate (CER), mean time to germination (MTG), mean time to coleoptile emergence (MTCE), percentage of coleoptile emergence (PCE), percentage of final germination (PFG), coleoptile length (CL), radicle length (RL), coleoptile to radicle ratio or allometric coefficient (CL/RL), radicle dry matter (RDM), and coleoptile dry matter (CDM) were evaluated in all treatments. The final germination percentage test was performed according to ISTA rules [15] at 15 °C in four replications based on the sum of the ratio of the total germinated seeds to the number of days after incubation (Equation 1). In this equation, (Ni) is the total number of germinated seeds up to the day (i), and Ti is the number of days between the first day and the last day of counting. Germination rate (Equation 2) and mean time to germination (Equation 3) were also calculated using the Maguire method in which GR is the sum of germinated seeds at two consecutive counts (Ni) divided by (Di), which is the number of days from the beginning of the count.

$$\sum G.I = N_i / T_i \qquad (1)$$

$$GR = \sum N_i / D_i \qquad (2)$$

$$MTG = \sum D_i / N_i \qquad (3)$$

Radicle and coleoptile length of normal seedlings were measured according to germination standards [15]. In order to determine the dry weight of radicles and coleoptiles, each of the experimental treatments was separately placed in an oven at 72 °C for 48 hours, and the dry weight of each replicate was measured in milligrams.

2.3. Statistical analysis

The two-factor factorial experiment was conducted in a completely randomized design with four replications. Data were analyzed using SAS statistical software. Mean data were compared using Duncan's test at 5% probability level.

3. Results

3.1. Effect of radiation on germination and seedling growth indices

A significant effect of radiation was recorded in all germination and growth indices of barley seedlings except for GR and CER (Table 2).

The final germination percentage of irradiated cultivars (93.58%) was significantly higher than that of non-irradiated cultivars (92.4%). However, RL of irradiated cultivars significantly decreased (5.62 cm) in comparison to non-irradiated control (6.28 cm)

Irradiated cultivars had significantly higher values of PFG (93.58%), MTG (41.24), MTCE (36.14), CL/RL (2.44), and CDM (0.22 g). On the other hand, CL (5.62 cm), RL (4.03 cm), and RDM (0.09 g) of control were significantly higher.

Table 2. Comparison of means between the 0.2 KGy gamma-irradiated barley seeds and the non-irradiated control cultivars in terms of germination and early growth indices.

Treatment	GR	CER	MTG	MTCE	PCE (%)	PFG (%)	CL (cm)	RL (cm)	CL/RL	CDM (g)	RDM (g)
Irradiated	1.37^{a}	1.93^{a}	41.24^{a}	36.14^{a}	90.31^{a}	93.58^{a}	5.62^{b}	4.03^{b}	2.44^{a}	0.22^{a}	0.09^{b}
Control	1.42^{a}	2.24^{a}	40.90^{b}	33.37^{b}	92.32^{b}	92.40^{b}	6.28^{a}	4.97^{a}	1.63^{b}	0.18^{b}	0.11^{a}

Means with the same letter in each column are not significantly different at 5% level of probability

3.2. Effect of cultivar on germination and growth indices

The mean results of each cultivars under both treatments were calculated (Table 3). 'Bahman' cultivar had the highest MTG, PCE, PFG, and RL while 'Makouee' cultivar scored the highest CER, MTCE, CL, and CL/RL values. ON the other hand, 'Behrokh' was the cultivar with the highest GR. 'Youssef' recorded the highest dry matter weights in radicle and coleoptile among the studied cultivars. It can be noticed that cultivars with high GR had lower MTG. On the other hand, cultivars that had a higher CER had a higher CL/RL ratio.

Table 3. Comparison of means between the different used barley cultivars in terms of germination and early growth indices.

Cultivar	GR	CER	MTG	MTCE	PCE (%)	PFG (%)	CL (cm)	RL (cm)	CL/RL	CDM (g)	RDM (g)
Behrokh	1.47^{a}	2.56^{a}	40.24^{b}	31.52^{b}	91.87^{a}	92.88^{b}	5.16^{b}	3.23^{b}	1.69^{a}	0.16^{b}	0.08^{b}
Bahman	1.34^{b}	1.21^{b}	41.82^{a}	36.28^{a}	93.74^{a}	95.27^{a}	6.40^{a}	5.57^{a}	1.27^{ab}	0.17^{b}	0.10^{b}
Makouee	1.37^{ab}	2.79^{a}	41.28^{ab}	37.24^{a}	89.68^{b}	91.66^{b}	7.16^{a}	4.42^{a}	1.71^{a}	0.21^{a}	0.14^{a}
Youssef	1.39^{ab}	1.78^{ab}	41.15^{ab}	33.99^{b}	90.00^{b}	91.25^{b}	5.08^{b}	4.91^{a}	1.09^{b}	0.22^{a}	0.16^{a}

Means with the same letter in each column are not significantly different at 5% level of probability

4. Discussion

It was reported that wheat seeds produced longer coleoptiles under 100 Gy gamma ray treatment. On the other hand, shorter coleoptiles were observed under higher doses (200, 300, and 400 Gy) [9]. [10] reported that gamma-ray irradiation decreased coleoptile length of the germinated corn seeds which is similar to the current results in barley. However, the current research results differ from other researches, which reported higher PFGs in control (no radiation) when compared to 0.2 KGy irradiated barley [13] and corn [10] seeds.

Previously, [9] results showed that gamma rays induced a significant RL increase in wheat cultivars and the highest RL and RDM were observed under 100 Gy dose while increasing gamma ray dose to 200 Gy resulted in 40 % reduction in RL, which is similar to the current results. Furthermore, [11] reported that gamma irradiation reduced stem and root length in the germinated lentil seeds. However, the current results differ from those reported in barley under lower radiation doses [14] since 10-20 Gy radiation dosage resulted in root and sprout length increase compared to the non-irradiated control.

The significant differences in RDM and CDM between irradiated samples and the non-irradiated control lead to the conclusion that a different material partition scheme took place under irradiation treatment. This different partitioning resulted in an increase in coleoptile dry matter and a decrease in radicle dry matter compared to control.

It was evident that regardless of the genetic material, gamma irradiation can induce significant impacts on the quantity and quality of the emerged barley seedlings. The radiation dosage used in the current experiment resulted in a significant overall increase in the final germination percentage, which might be of substantial economic potential. However, close observation is necessary for the later phases of plant growth since irradiation can heavily affect the new seedlings and increase mortality in the days following germination [10].

5. Conclusion

Although germination rate, coleoptile emergence rate, coleoptile length, radicle length, and radicle dry weight of gamma-irradiated cultivars decreased compared to the control, the irradiated cultivars had higher final germination percentage, coleoptile length to radicle length ratio, and coleoptile dry weight. Additionally, the irradiated cultivars had a longer average germination time and longer mean duration of coleoptile emergence compared to non-irradiated cultivars. More studies are needed to monitor the later phases in plants that emerged from irradiated seeds and evaluate whether seed irradiation can affect overall productivity in the studied cultivars.

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